NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: GP

October 15, 1970

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General
Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned
U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,271,140

Corporate Source : Lewis Research Center

Supplementary
Corporate Source :

NASA Patent Case No.: XLE-00726

Gayle Parker

Enclosure:
Copy of Patent

N71-15644

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HIGH TEMPERATURE COBALT-BASE ALLOY

John C. Freche, Fairview Park, Stanley J. Klima, Rocky River, and Richard L. Ashbrook, Berea, Ohio, assignors to the United States of America as represented by the National Aeronautics and Space Administration

No Drawing. Filed Mar. 26, 1964, Ser. No. 355,126
4 Claims. (Cl. 75—170)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an improved cobalt-base alloy having a high load carrying capacity at elevated temperatures. The invention is further concerned with a cobalt-base alloy that is stable in a high vacuum and exhibits good corrosion resistance characteristics.

Present day aerospace structures require alloys which can be subjected to the dual environment of liquid metals on one surface and a high vacum on the other. Examples of such structures are components for turbo-electric space power systems in which nuclear power is converted to electric power through the medium of a closed thermodynamic cycle. Such systems have many components, such as reactor, radiator, ducting and various turbo-generator parts, and the ducting as well as the radiator components present some extremely critical materials problems. For example, the material in these components, must be ductile to facilitate forming as well as corrosion resistant and have good high temperature strength properties. Pump and turbine components represent other examples of aerospace structures requiring improved high temperature strength and ductility.

Certain stainless steels as well as wrought nickel and cobalt-base alloys have been considered for ducting in turbo-electric space power systems. Also refractory metal alloys of columbium have been considered for temperatures of 2000° F. and above.

Each of these types of materials has certain limitations when considered for use in turbo-electric space power system ducting applications. For example, stainless steels are limited to approximately 1400° F. for long life, even at the relatively low stress levels likely to be encountered in ducting for turbo-electric space power systems. Wrought commercial cobalt and nickel-base alloys are limited to approximately 1600° and 1700° F., respectively, for long life at low stress levels. Some metals tend to evaporate more than others in a high vacuum because the vapor pressures of the various metals differ, and chromium as well as aluminum are particularly susceptible to evaporation losses. Virtually all stainless steels, cobalt-, and nickel-base alloys contain appreciable quantities of chromium, and most nickel-base super alloys contain aluminum, as well. Therefore, evaporation of these elements may occur during long time exposure of these alloys to a high vacuum environment. As a consequence, the structural integrity of these alloys may be affected. The manner in which the alloying element is tied up in the metal matrix can greatly affect this process. By way of example, a solid solution of chromium in a metal matrix would be very likely to be more readily affected by evaporation than chromium that is part of an inter-metallic minor phase.

A solution to the problem would be the elimination of high vapor pressure alloying elements in the alloys. From a corrosion resistance standpoint, cobalt resists corrosion by mercury more than nickel but less than iron. It appears that cobalt is at least equivalent to nickel in corrosion resistance in alkali metals up to the limit of its useful temperature range. Certain stainless steels, though acceptable up to 1600° F. in contact with the alkali metals,

show a low compatibility with mercury if they have a high nickel and/or a high chromium content. Nickel-base alloys are not compatible with mercury, but may be used with the alkali metals up to approximately 1700° F. Refractory columbium alloys, although having excellent elevated temperature strength characteristics and corrosion resistance to both mercury and the alkali metals, are very subject to oxidation. This makes pilot or ground tests of prototype units using this material extremely difficult and expensive.

It is, therefore, an object of the present invention to provide a cobalt-base alloy capable of high load-carrying capacity at temperatures up to 1850° F. so that the increases in efficiency possible through operation at high cycle temperatures may be realized with advanced turbo-electric space power systems.

Another object of the invention is to provide an alloy which has resistance to the corrosion of contacting heat transfer and turbine-drive-fluid media.

Another object of the invention is to provide an alloy which is stable in the high vacuum of space at elevated temperature.

A further object of the invention is to provide a cobalt-base alloy that is workable so that it may be fabricated into sheet or tubing for ducting and radiator applications.

These and other objects and advantages of the invention will be apparent from the specification which follows.

The present invention is embodied in alloys having the following composition range:

Cobalt	From about 48.5% to about 84.5%.
Tungsten	From about 15% to about 45%.
Titanium	From about 0.4% to about 2.5%.
Zirconium	From about 0% to about 3.0%.
Carbon	From about 0.1% to about 1.0%.

A preferred alloy has the following composition:

	Percent, about
Cobalt	73.6
Tungsten	25.0
Titanium	1.0
Zirconium	0
Carbon	0.40

The addition of zirconium up to about three percent to the above preferred alloy composition further improves the strength properties. For example, 1800° F.—15,000 p.s.i. rupture lives in air in excess of 350 hours and 1850° F.—15,000 p.s.i. rupture lives in excess of 90 hours have been obtained with addition of zirconium to the preferred composition in which the cobalt content is lowered to accommodate the addition. Thus, a more preferred alloy has the following composition:

	Percent
Cobalt	73.1
Tungsten	25.0
Titanium	1.0
Zirconium	0.5
Carbon	0.4

The subject alloys were prepared with one of the simplest possible casting techniques. The melt was made in a refractory crucible of zirconia which was placed in a high frequency induction coil.

The bottom of a cold zirconia crucible was covered with a small quantity of electrolytic cobalt. On top of this, carbon was placed in the form of one inch diameter compacts of lamp black. This was covered with briquetted titanium sponge. The whole was covered with electrolytic cobalt nearly filling the crucible. A cylindrical shield was placed around the top of the crucible, and a flow of argon was directed at the top of the charge.

Once the charge had begun to settle, the remaining cobalt was added. When this portion of the charge was completely melted, tungsten was added in the form of short lengths of 1/8" diameter rod.

The melt was then superheated to approximately 3050° F. and held for three minutes to insure that the tungsten was melted. The melt was then allowed to cool to approximately 2900° F. and was poured. During pouring the inert gas coverage was removed. Melts were hand poured into investment molds heated to 1600° F., and were permitted to come to equilibrium temperature naturally without speeding up the process artificially. These alloys have also been prepared by more complex techniques, such as closely controlled vacuum melting, which resulted in further improvements in alloy properties. Thus, by introducing a higher degree of complexity in the casting process, an improved alloy results.

The alloys of this invention derive their high elevated temperature strength from the solid solution strengthening of the cobalt by tungsten, by the precipitation of the intermetallic WCo_3 phase, and by the formation of dispersed tungsten and titanium carbides. Samples of one of the preferred compositions, Co-25W-1Ti-0.4C, made in accordance with the simplified casting technique described above provided an average ultimate strength of 44,900 p.s.i. and an average elongation of 12.5% at 1800° F.

A comparsion of stress rupture properties of the preferred compositions with some of the strongest cobalt-base alloys commercially available is shown in Table I.

TABLE I

Alloy	Stress, p.s.i.	Temp., ° F.	Average Rupture Life in air, hrs.
Co-25W-1Ti-0.4C	15,000	1,800	>90
Co-25W-1Ti-0.5Zr-0.4C	15,000	1,800	>200
	15,000	1,850	>90
W1-52 (Cast)	15,000	1,800	<60
HS-31 (Cast)	15,000	1,800	<10
HS-25 (Wrought)	15,000	1,800	<10

The results of capsule corrosion tests of several alloys in mercury are shown in Table II.

TABLE II

Alloy	Temp., ° F.	Exposure Time, hrs.	Penetration, mils
Co-25W-1Ti-0.2C	1,200	301	2.38
			3.52
	1,300	300	3.89
			4.01
	1,100	301	2.70
	1,200	301	8.26
	1,100	294	5.88
			6.15
	1,200	294	9.43
			13.97
	1,300	81	11.2

From the above information, it is evident that the high strength of the alloys of the present invention is superior to that of commonly used cobalt-base alloys. Cobalt-base alloys are used for turbine vanes and buckets in jet engines, and these components are generally coated to improve oxidation resistance to combustion gases. It is evident that the improved alloys of the present invention are superior for these turbine components when the proper oxidation resistant coatings are used. In addition, the combination of high strength and ductility of this alloy series makes these alloys, when coated, desirable for use in combustion chamber and tailpipe assemblies.

The resistance to evaporation of this alloy series makes it applicable to high temperature vacuum furnace components where loss of strength can be a serious problem. It could be used as-cast for structural components or as sheet for radiation shields. In the latter application, where loading is not particularly severe, these alloys may be used up to about 2200° F. or even higher, and no coatings are required for this application.

It is understood that equivalents or modifications of or substitutions for parts of the above described embodiments of the invention may be made without departing from the spirit of the invention or the scope of the subjoined claims.

What is claimed is:

1. A cobalt base alloy capable of high load carrying capacity at elevated temperatures consisting essentially of from 48.5% to 84.5% cobalt, from 15% to 45% tungsten, from 0.4% to 2.5% titanium, and from 0.1% to 1.0% carbon.

2. The cobalt base alloy of claim 1 additionally containing up to 3% zirconium, the cobalt content of said alloy being adjusted to accommodate the addition.

3. A cobalt base alloy capable of high load carrying capacity at elevated temperatures consisting essentially of 73.6% cobalt, 25.0% tungsten, 1.0% titanium, and 0.4% carbon.

4. A cobalt base alloy capable of high load carrying capacity at elevated temperatures consisting essentially of 73.1% cobalt, 25.0% tungsten, 1% titanium, 0.5% zirconium, and 0.4% carbon.

References Cited by the Examiner

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DAVID L. RECK, *Primary Examiner.*

R. O. DEAN, *Assistant Examiner.*